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ENSO and the hydrology of the Sinnamary River (French Guiana) during the rainy season: will future El Niño events increase the impact of the Petit Saut dam on downstream fish communities?

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With 8 figures and 2 tables

Abstract: This study is based on 27 series of daily water level (DWL) records in the downstream reaches of the Sinnamary River during the November to June rainy season: 22 series prior to dam closure, two series during filling and three series during dam operation. Five of these series (4 before and 1 during dam operation) corresponded with El Niño events, six (all prior to dam closure) with La Niña events. Before dam closure, monthly DWL were significantly higher during La Niña events from November to June, and significantly lower during El Niño events in January, February, May and June, than during years with no particular El Niño–Southern Oscillation (ENSO) event. Maximum monthly DWL were significantly higher during La Niña events than during years with no particular ENSO event in February, March and May only. The date of occurrence of the seasonal maximum DWL did not vary significantly with ENSO events. A greater number of days with high DWL were recorded during rainy seasons corresponding with La Niña events than during years with no particular ENSO event but El Niño events reduced the occurrence of high DWL in June only. Dam operation significantly increased monthly DWL in the downstream reaches of the Sinnamary River from November to January whatever the ENSO event considered. During the 1997–98 rainy season, which corresponded with an El Niño event, the dam amplified the impact of lower rainfall by completely removing high DWL. It is concluded that in the future, dam operators will have to restore periods of high DWL during rainy seasons characterised by El Niño events, or present nurseries will no longer play their role for sustaining fish diversity in the downstream reaches of the Sinnamary River.

Key words: El Niño–Southern Oscillation, flow regime modifications, fish diversity, Neotropics.

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Introduction

Natural flow variations play a central role in organising river ecosystems, their biodiversity, production and sustainability (POFF et al. 1997). Accumulated evidences suggest that the full range of natural intra- and interannual variations of hydrological regimes is critical in sustaining the full native biodiversity of aquatic ecosystems (RICHTER et al. 1997). In several regions of the world, interannual variations of river flow has been related to the El Niño–Southern Oscillation (ENSO), a large scale coupled ocean-atmosphere oscillation in the Pacific Ocean. Warm (El Niño) ENSO phases are associated with below-normal rainfall and river discharge in Australia (SIMPSON et al. 1993, CHIEW et al. 1998) and affect low flows, peak flows, and flood frequency of rivers throughout New Zealand (MOSLEY 2000). In South America, El Niño events tend to reduce the discharge of the Amazon and increase that of the Paraná River (AMARASEKERA et al. 1997).

For numerous temperate rivers, flow regulation now superposes on natural variations of hydrological regimes (DYNESIUS & NILSSON 1994). Alteration of river flow by dams is one of the most important factors influencing riverine ecosystems because it interrupts within-channel patterns and processes (WARD & STANFORD 1983) and modifies lateral interactions between channel and floodplain (WARD & STANFORD 1995). When these environments are pushed outside their range of natural variability, all aquatic communities are strongly endangered (RESH et al. 1988).

In the early 1990s, only 5 % of the South American rivers presented an altered flow (BRAVARD & PETTS 1993); however, the increasing needs to produce electricity will speed up the construction of hydroelectric dams in the future (PETTS 1990, RIBEIRO et al. 1995). In French Guiana, Électricité de France obtained in the late 1980s the mandate to construct a dam at 'Petit Saut', the first set of rapids (moving upstream) on the Sinnamary River. The gates of this dam were first closed in January 1994 and the reservoir was filled in mid-1995. In agreement with French regulations the downstream flow was cut to 100 m^3/s during most of the 1994–95 and 1995–96 rainy seasons in order to fill the reservoir. This period of low water levels downstream of the dam immediately impacted the assemblages of young fishes (PONTON & COPP 1997, PONTON et al. 2000). Indeed, most fish species of the Sinnamary River naturally reproduce during periods of high water levels (PONTON & DE MÉRONA 1998) and their progeny use the tributaries and their adjacent areas as nurseries when they are flooded (MÉRIGOUX et al. 1999, MÉRIGOUX & PONTON 1999). The mean water levels of the river, their variability, and the number of days they exceed certain values, thus play an important role for explaining the temporal variations in densities of young fishes found in tributaries (MÉRIGOUX & PONTON 1999). This strongly suggests that the more dam operations reduce the flow regime during the rainy season (i. e. when most fish species reproduce), the more the sustainability of fish communities in downstream reaches of the river is threatened.

The aims of this study were 1) to document the effects of warm (El Niño) and cold (La Niña) ENSO events on the hydrology of the Sinnamary River during the rainy season from a long series of daily water level records before dam closure, 2) to examine how the Petit Saut dam operation modified the downstream flow, especially during the 1997–98 El Niño events, 3) to discuss how dam operation in the future may increase the impact of El Niño events on downstream fish communities, and to suggest tentative remedies.

Study area

The Sinnamary River is the fifth largest river of French Guiana (Fig. 1). It has a length of approximately 260 km, a mean annual discharge of 230 m^3/s and can be classified as a medium-sized river sensu DYNESIUS & NILSSON (1994). Its drainage basin covers approximately 6565 km^2 and receives annual precipitation averaging 3000 mm (for a description of the entire river system, see BOUJARD 1992 and TITO DE MORAIS et al. 1995). Downstream from the rapids where the dam has been built, its lower course meanders through an old flat coastal plain where water levels are under the influence of the tide that regularly elevates the river's fresh waters.

In 1988, Electricité de France started to build a dam (total length = 750 m, maximum height = 44 m) at Petit Saut rapids (Fig. 1). This dam has the capacity to generate 111 MW when releasing 430 m^3/s^{-1} from its four generators and presently provides approximately 80 % of the electricity consumed in French Guiana.

Material and methods

The records of four different gauging stations were used to reconstruct a long time series of natural daily water levels (DWL) in the downstream reaches of the Sinnamary River. The gauging stations (Fig. 1) were those set by the ORSTOM Hydrological Section at: (1) "Adieu Vat", near the confluence between the Courcibo and the Sinnamary Rivers, from July 1953 to February 1958 and from November 1968 to December 1976, (2) "Saut Tigre", on the Sinnamary River a few kilometres upstream of its confluence with the Courcibo River, from November 1968 to March 1993, (3) "Petit Saut upstream", approximately 500 m upstream from Petit Saut rapids, from January 1982 to September 1992, and (4) "Petit Saut downstream", approximately 300 m downstream from Petit Saut rapids, starting in January 1990. At the gauging stations upstream from Petit Saut rapids ("Adieu Vat", "Saut Tigre", and "Petit Saut upstream"), DWL corresponded to the mean of all the values recorded over 24 hours. At the "Petit Saut downstream" gauging station, DWL corresponded to the minimum value obtained over 24 hours in order to remove the effect of tides.

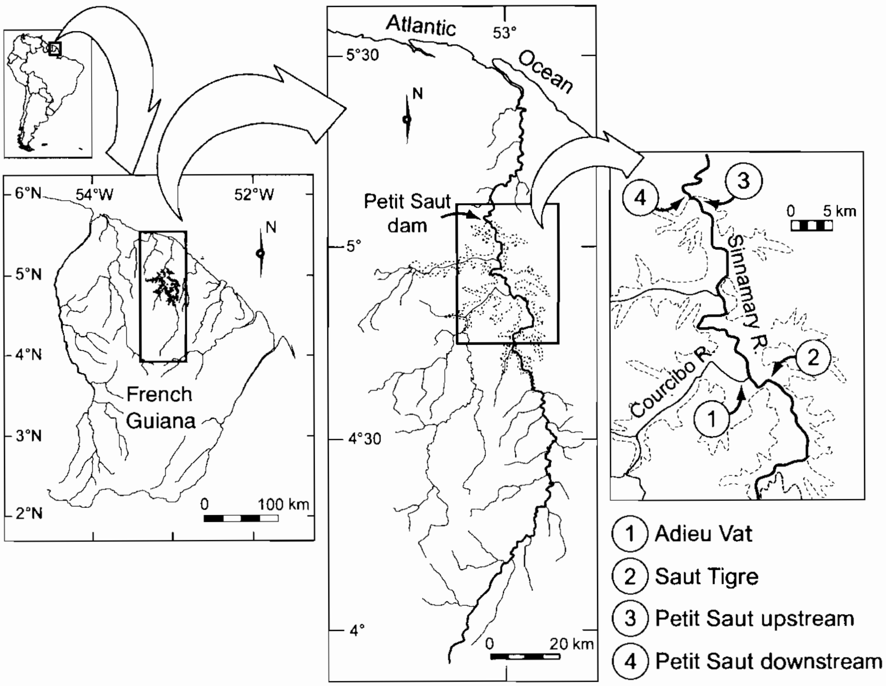

Fig. 1. The Sinnamary in French Guiana, South America, as it appeared before impoundment with its most important tributaries, and the locations of Petit Saut dam and the gauging stations at: (**1**) "Adieu Vat" from July 1953 to February 1958 and from November 1968 to December 1976, (**2**) "Saut Tigre" from November 1968 to March 1993, (**3**) "Petit Saut upstream" from January 1982 to September 1992, and (**4**) "Petit Saut downstream" in January 1990 and afterwards. The dashed line indicates the present high water limits of Petit Saut Reservoir.

Piecewise linear regressions, i. e. linear relations in pieces where the slope and intercept are different for each piece (Wilkinson et al. 1996, Engelman 1999), were fitted separately to a) DWL at 'Saut Tigre' against DWL at 'Adieu Vat', b) DWL at 'Petit Saut upstream' against DWL at 'Saut Tigre', and c) DWL at 'Petit Saut downstream' against DWL at 'Petit Saut upstream' (Fig. 2 and Table 1) with the NONLIN module of SYSTAT® 9.0 (Engelman 1999). By using relations a, b, and c between 1954 and 1957, relations b and c between 1969 and 1977 and in 1980, relation c between 1982 and 1989, and direct observations from 1990 and thereafter, a total of 26 years of DWL at Petit Saut downstream (DWL_{PSD}) before dam closure, and of five years of DWL_{PSD} from 1994 and thereafter, were obtained (Fig. 3).

Naturally, Sinnamary water levels increase from minimum values in late October – early November to peak values in May – June (Fig. 3). This work being aimed at studying the water level variations during the rainy season, the DWL_{PSD} from 1st November one year to 30th June the following year were retained for subsequent analyses. A total of 27 series of November-to-June DWL_{PSD} of were kept: 22 series prior to dam

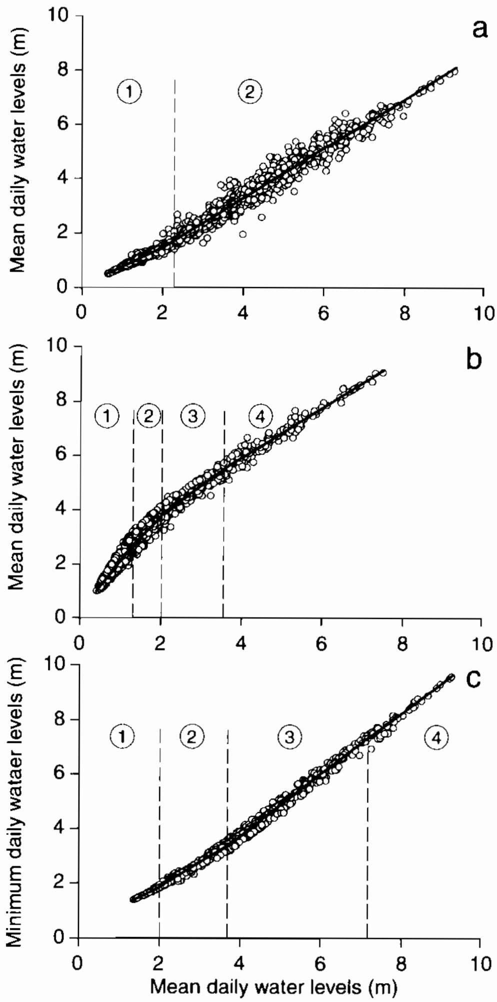

Fig. 2. Piecewise linear regressions relating **a)** daily water levels (DWL) at Saut Tigre to DWL at Adieu Vat, **b)** DWL at Petit Saut upstream to DWL at Saut Tigre, and **c)** DWL at Petit Saut downstream to DWL at Petit Saut upstream. The vertical dashed lines correspond to the limit of the different pieces whose equations are presented in Table 2.

closure, two series during impoundment and three series during dam operation (Fig. 3). As the consequences of impoundment on DWL_{PSD} have been presented elsewhere (PONTON & VAUCHEL 1998), the 1993–94 and 1994–95 series will not be considered further in this study.

Between 1948 and 1998, the National Oceanographic and Atmospheric Administration (NOAA) Climate Diagnostic Center listed eight El Niño and eight La Niña events

Table 1. Parameters of the piecewise linear regressions relating the different gauging stations two by two for different limits of daily water levels (DWL in m). With N: number of observations, a: slope of each piece, SE_a: standard error of a, b: intercept of each piece, SE_b: standard error of b, and *P*: associated probability. The numbers in circles correspond to the different phases presented graphically on Fig. 2.

Relationships Limits	N	a	SE_a	b	SE_b	*P*
a) Saut Tigre vs. Adieu Vat						
① DWL ≤ 1.98	1047	0.71	0.01	0.06	0.01	<0.001
② DWL > 1.98	1907	0.91	0.01	−0.35	0.01	<0.001
b) Petit Saut upstream vs. Saut Tigre						
① DWL ≤ 1.34	1050	1.89	0.02	0.24	0.02	<0.001
② 1.34 < DWL ≤ 2.01	663	1.49	0.04	0.78	0.07	<0.001
③ 2.01 < DWL ≤ 3.81	568	1.08	0.01	1.65	0.04	<0.001
④ DWL > 3.81	165	0.92	0.01	2.23	0.07	<0.001
c) Petit Saut downstream vs. Petit Saut upstream						
① DWL ≤ 2.01	71	0.74	0.02	0.37	0.03	<0.001
② 2.01 < DWL ≤ 3.67	378	0.90	0.01	0.06	0.02	<0.001
③ 3.67 < DWL ≤ 7.05	403	1.15	0.01	−0.89	0.04	<0.001
④ DWL > 7.05	52	1.08	0.04	−0.39	0.28	<0.001

for the November-to-March period (Climate Diagnostic Center 2000 a). This classification is based on the Pacific Ocean surface temperature along the equator from 150°W to the date line (Climate Diagnostic Center 2000b). According to this list, each series of DWL_{PSD} was thus sorted out as corresponding to no particular ENSO event ('other' years or 'O' hereafter), to a La Niña event ('LN' hereafter) or to an El Niño event ('EN' hereafter). As the classification of ENSO events is not yet standardised (Hill et al. 2000), the pertinence of sorting rainy seasons among 'O', 'LN', or 'EN' was checked by calculating the corresponding mean value of the Southern Oscillation Index (SOI) between November and March. SOI is defined as the normalised difference in surface pressure between Tahiti, French Polynesia, and Darwin, Australia, and is used as a measure of the strength of the trade winds (IRI/LDEA 2000).

The differences between 'O', 'LN' and 'EN' rainy seasons in 1) the distributions of the monthly DWL_{PSD}, 2) the distributions of the monthly maximum DWL_{PSD}, 3) the Julian date of occurrence of the annual maximum DWL_{PSD}, and 4) the seasonal and monthly duration in days of high pulses at Petit Saut downstream, were then evaluated before dam closure and during dam operation. Following Richter et al. (1996), high pulses were defined as $DWL_{PSD} > 75^{th}$ percentile of all DWL_{PSD} recorded before dam closure. Shifts in the distributions of the parameters were tested two by two with the Wilcoxon-Mann-Whitney test (also known as the Wilcoxon rank-sum test) with StatXact®, a statistical software for exact distribution-free inference using the algorithms

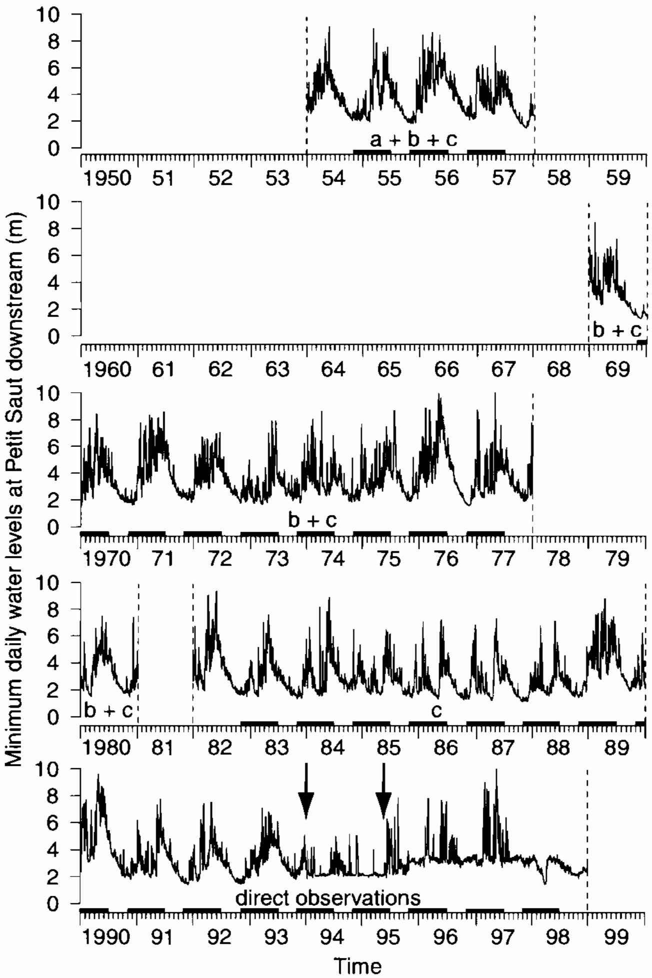

Fig. 3. Minimum daily water levels at Petit Saut downstream gauging station obtained by using relations a, b, and c of Table 1 between 1954 and 1957, relations b and c between 1969 and 1977 and in 1980, relation c between 1982 and 1989, and direct observations from 1990 onwards. Horizontal black bars correspond to the November to June periods used for subsequent analyses. The vertical arrows indicate the closure of Petit Saut dam on 4 January 1994 and the end of reservoir filling. Note the absence of floods during the 1997–98 rainy season.

developed by Mehta & Patel (1995) for performing permutation tests. The P value associated to each test is either based on complete enumeration of the original data, or on 10000 random permutations of them, depending on the number of observations (Mehta & Patel 1995).

Table 2. November to June rainy seasons for which calculated or recorded daily water levels at Petit Saut downstream (DWL_{PSD}) corresponded to El Niño, La Niña, and to no particular ENSO event (Other) as defined by the Climate Diagnostic Center (2000 a) for the winter period (November to March). This classification corresponds to warm or cold episodes of great strength (W+ or C+), moderate strength (W or C), low strength (W− or C−), or to no noticeable episode, observed in the tropical Pacific from October to December (OND) and from January to March (JFM) by the Climate Diagnostic Center (2000 b). This classification is generally in agreement with the mean values of the Southern Oscillation Index (SOI, IRI/LDEA 2000) calculated for the November-to-March period. With *: rainy season during impoundment. **: rainy season during dam operation.

	Rainy season for which (DWL_{PSD}) exist	Warm and cold episodes in the tropical Pacific OND	JFM	Mean SOI November to March
El Niño	1972–73	W+	W	−0.88
	1982–83	W+	W+	−3.64
	1986–87	W	W	−1.62
	1991–92	W	W+	−2.18
	1997–98**	W+	W+	−2.42
La Niña	1954–55	C	C	0.56
	1955–56	C+	C	1.22
	1970–71	C	C	1.62
	1973–74	C+	C+	2.36
	1975–76	C+	C	1.60
	1988–89	C+	C+	1.32
Other	1956–57	C−		0.16
	1969–70	W−	W−	−0.58
	1971–72	C−		0.36
	1974–75	C−	C−	0.14
	1976–77	W−		−0.16
	1983–84	C−	C−	−0.10
	1984–85	C−	C−	0.10
	1985–86			−0.18
	1987–88	W	W−	−0.36
	1989–90			−0.98
	1990–91	W−	W−	−0.42
	1992–93	W−	W−	−1.08
	1993–94*	W−		−0.40
	1994–95*	W	W	−0.64
	1995–96**	C−	C−	0.14
	1996–97**			0.36

Results

Five El Niño and six La Niña events listed by the NOAA Climate Diagnostic Center for the November to March period corresponded to rainy seasons for which DWL_{PSD} values were recorded or calculated (Table 2). This subjective classification was in agreement with the mean value of the Southern Oscillation Index (SOI) from November to March: 'EN' rainy seasons corresponded to mean SOI varying from −0.88 to −3.64, 'LN' rainy seasons to mean SOI varying from 0.56 to 2.36, while for 'O' rainy seasons mean SOI varied between −1.08 and 0.36.

Before dam closure, November to June monthly DWL_{PSD} were always significantly higher during La Niña events than during 'O' years (Fig. 4). The differences between median values were > 1 m in February, March and May, and even reached > 2 m in April. The monthly DWL_{PSD} during 'EN' rainy seasons were significant lower than those of 'O' ones in January, February, May and June only (Fig. 4) but with the exception of June, the differences between median values were always < 1 m. Dam operation significantly increased monthly DWL_{PSD} from November to December whatever the ENSO event considered. It also increased monthly DWL_{PSD} from February to April during 'O' rainy seasons but remarkably decreased monthly DWL_{PSD} from March onwards during the 1997–98 El Niño event (Fig. 4).

Maximum monthly DWL_{PSD} were significantly higher during 'LN' than during 'O' years in February, March, and May, whereas they were significantly lower during 'EN' rainy seasons than during 'O' ones in January only (Fig. 5). During dam operation monthly maximum DWL_{PSD} remained within the natural range of observations from November to January independently of ENSO events (Fig. 5). During the 'EN' rainy season of 1997–98, monthly maximum DWL_{PSD} remained always lower than the minimum value observed before dam closure from February onwards. In May, the maximum DWL_{PSD} was even > 1 m below the lowest value ever observed before dam closure.

Maximum DWL_{PSD} during the rainy season occurred naturally as early as at the beginning of November and as late as mid-June without significant influence of ENSO events (Fig. 6). In 1996, 1997 and 1998 the annual maximum DWL_{PSD} occurred within the range of natural observations but in 1998 the maximum DWL_{PSD} was recorded in January, i. e. earlier than usual during 'EN' rainy seasons (Fig. 6).

Before dam closure the number of days with DWL_{PSD} > 4.85 m (i. e. > 75th percentile of all DWL_{PSD} of the 22 rainy seasons before dam closure) varied from 15 to 132 (Fig. 7). During 'LN' rainy seasons, the number of high pulses were significantly greater than during 'EN' or 'O' periods (Fig. 7), especially from February to April and in June (Fig. 8). After dam closure, the number of days with DWL_{PSD} > 4.85 m during the two 'O' rainy seasons remained within

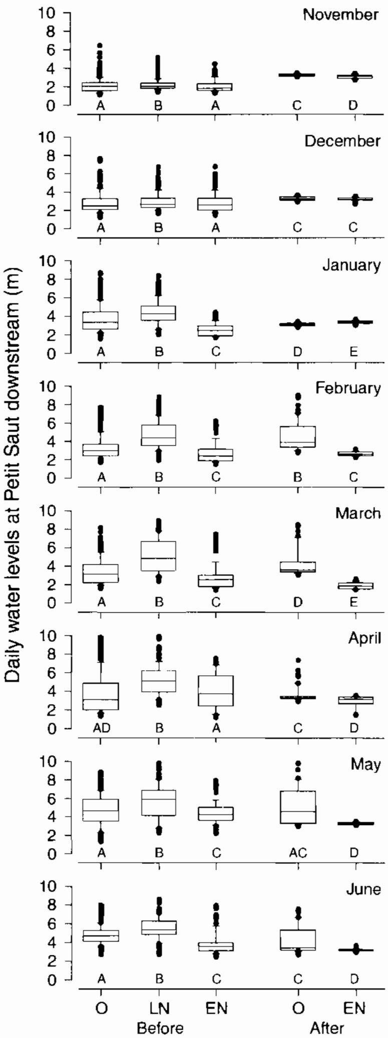

Fig. 4. Monthly daily water levels (in m) at Petit Saut downstream in rainy seasons not characterised by El Niño or La Niña events (O), rainy seasons characterised by La Niña events (LN), rainy seasons characterised by El Niño events (EN) before dam closure ('Before', 22 rainy seasons) and during dam operation ('After', 3 seasons). Boxes contain 50 % of the data (lower limit = first quartile and upper limit = third quartile), the bar in each box represents the median value, the whiskers extend to 10^{th} and 90^{th} percentiles, and the dots represent values outside this range. Different letters under two boxes indicate that one distribution is significantly ($P<0.05$) shifted from the other (one-sided Wilcoxon-Mann-Whitney test, Monte-Carlo estimate of the P value based on 10000 random permutations of the original data).

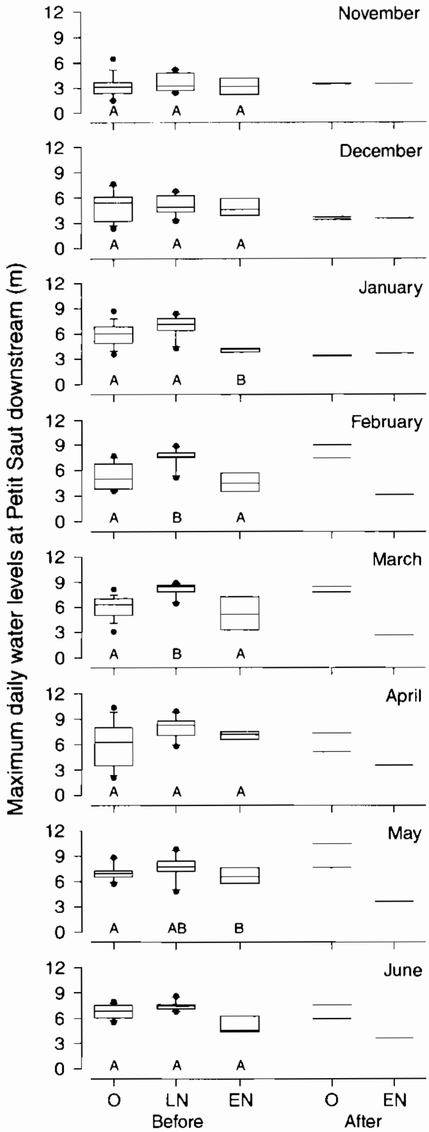

Fig. 5. Monthly maximum daily water levels (in m) at Petit Saut downstream in rainy seasons not characterised by El Niño or La Niña events (O), rainy seasons characterised by La Niña events (LN), rainy seasons characterised by El Niño events (EN) before dam closure ('Before', 22 rainy seasons) and during dam operation ('After', 3 rainy seasons). Boxes, bars within boxes, whiskers, and dots as in Fig. 4. No whisker indicates that 1st quartile = 10th percentile and 3rd quartile = 90th percentile. Each value during dam operation (3 rainy seasons only) is indicated only by a horizontal line. Different letters under two boxes indicate that one distribution is significantly ($P < 0.05$) shifted from the other (one-sided Wilcoxon-Mann-Whitney test, P value based on complete enumeration of the original data).

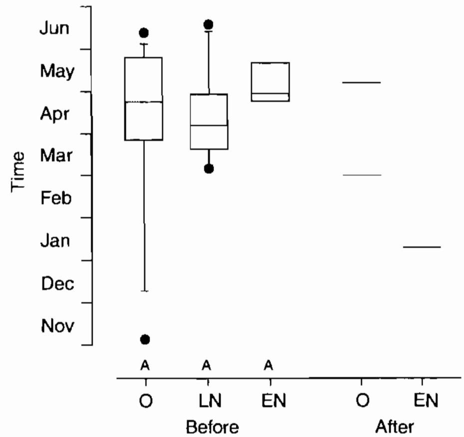

Fig. 6. Dates at which maximum daily water levels occurred at Petit Saut downstream between November and June for periods not characterised by El Niño or La Niña events (O), periods characterised by La Niña events (LN), periods characterised by El Niño events (EN) before dam closure ('Before', 22 rainy seasons) and during dam operation ('After', 3 rainy seasons). Boxes, bars within boxes, whiskers, and dots as in Fig. 4. No whisker indicates that 1st quartile = 10th percentile and 3rd quartile = 90th percentile. Each value during dam operation (3 rainy seasons only) is indicated only by a horizontal line. Identical letters indicate that no distribution is significantly shifted from the other (one-sided Wilcoxon-Mann-Whitney test, all P value based on complete enumeration of the original data > 0.05).

the range of natural values (Fig. 7 and 8) but in 1997–98, DWL_{PSD} never exceeded 4.85 m during the whole rainy season (Fig. 7 and 8).

Discussion

In contrast with large tropical rivers in which flooding is highly predictable (BAYLEY 1988), small Guianese rivers are well known for the extreme short-term variability in their discharge, which is linked to local rainy events (COVICH 1988, OUBOTER & MOL 1993). The present study demonstrates that great annual variations in the flow regime of Guianese rivers during the rainy season also occur under the influence of large climatic events. Until the end of the 1980s, annual variability in South American tropical rainfall was thought to be negligible but MOLION (1990) demonstrated that during warm (El Niño) ENSO phases rainfall is dramatically reduced over Amazonia whereas during cold (La Niña) events the convective activity, and thus rainfall, increase over this area. In accordance with these trends, the water levels in the downstream reaches of the Sinnamary River during the rainy season tended to be higher during La Niña events and lower during El Niño events. As a consequence, ad-

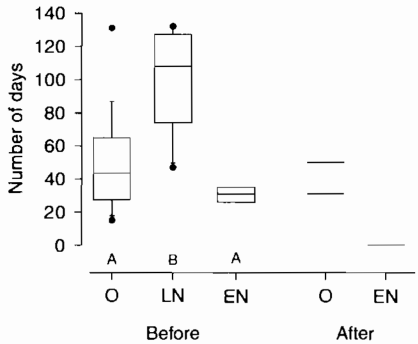

Fig. 7. Total number of days with water level > 4.85 m (i. e. > 75th percentile of all DWL of the 22 rainy seasons before dam closure) at Petit Saut downstream between November and June for rainy seasons not characterised by El Niño or La Niña events (O), rainy seasons characterised by La Niña events (LN), rainy seasons characterised by El Niño events (EN) before dam closure ('Before', 22 rainy seasons) and during dam operation ('After', 3 rainy seasons). Boxes, bars within boxes, whiskers, and dots as in Fig. 4. No whisker indicates that 1st quartile = 10th percentile and 3rd quartile = 90 th percentile. Each value during dam operation (3 rainy seasons only) is indicated only by a horizontal line. Different letters under two boxes indicate that one distribution is significantly ($P<0.05$) shifted from the other (one-sided Wilcoxon-Mann-Whitney test, P value based on complete enumeration of the original data).

jacent areas of the main channel and of the tributaries of the Sinnamary were probably often flooded, and over longer periods of time, during cold ENSO phases than during warm ones.

It can be assumed that not only within-year but also between-year variability in the flow regime of the Sinnamary River shapes the assemblages of fish early life stages. Indeed Mérigoux & Ponton (1999) demonstrated that the abundance of several young Characiformes fish taxa, as well as the taxon richness within this order, were positively related to the intensity and duration of flooding events. Characiformes fish, which reproduce mostly during the rainy season (Munro 1990, Ponton & de Mérona 1998), are thus directly influenced by extreme flow events during this period. Early life stages of Siluriformes, Gymnotiformes, Cyprinodontiformes, and Perciformes, whose abundance in the tributaries of the Sinnamary River is independent of flow variations (Mérigoux & Ponton 1999), can also be impacted, albeit indirectly, by extreme flow changes. Indeed, early life stages of all these fish species exploit a mosaic of habitats created and maintained by the natural hydrological variability of the river (see Poff et al. 1997). Abnormally low hydrological conditions in the main channel induce an increase in water velocity in the tributaries (Ponton & Vauchel 1998). In the long term, such a shift in the distribution of water velocity towards high values may change the channel morphology of

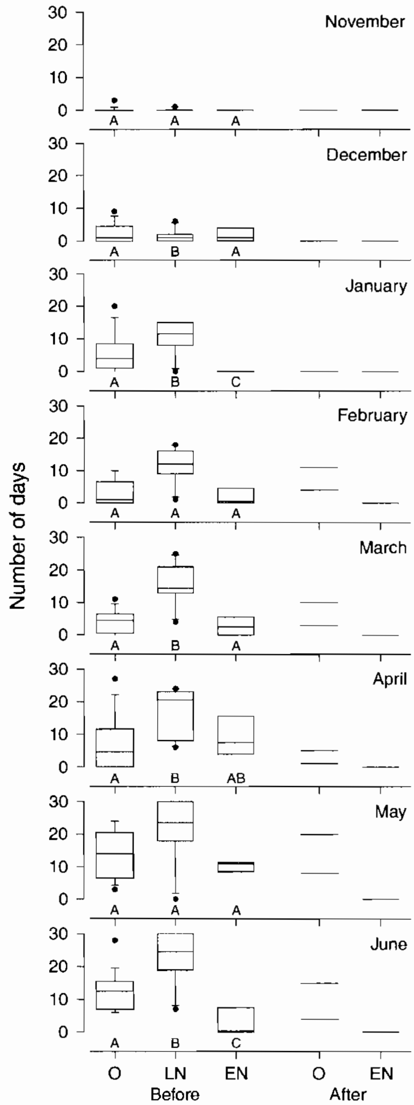

Fig. 8. Number of days with daily water level (DWL) > 4.85 m (i.e. > 75^{th} percentile of all DWL of the 22 rainy seasons before dam closure) at Petit Saut downstream for each month of rainy seasons not characterised by El Niño or La Niña events (O), rainy seasons characterised by La Niña events (LN), rainy seasons characterised by El Niño events (EN) before dam closure ('Before', 22 rainy seasons) and during dam operation ('After', 3 rainy seasons). Boxes, bars within boxes, whiskers, and dots as in Fig. 4. No whisker indicates that 1^{st} quartile = 10^{th} percentile and 3^{rd} quartile = 90^{th} percentile. Each value during dam operation (3 rainy seasons only) is indicated only by a horizontal line. Different letters under two boxes indicate that one distribution is significantly ($P<0.05$) shifted from the other (one-sided Wilcoxon-Mann-Whitney test, P value based on complete enumeration of the original data).

the tributaries and thus negatively influence the survival of the young fishes (see the discussion in PONTON & VAUCHEL 1998).

The data presented here suggest that Petit Saut dam operation can amplify the influence of El Niño events on the quantity of water released in downstream reaches of the Sinnamary River. During the 1997–98 rainy season, the high flows in that section of the river were completely removed by dam operation (Figs. 5 and 7). The conditions endured by the fishes thus resembled those of the 1993–94 and 1994–95 rainy seasons when the flow released from the dam was kept at 100 m^3/s (PONTON & VAUCHEL 1998). Although young fish assemblages had shown signs of recovery in 1996 following the restoration of water level variations resembling natural ones (PONTON et al. 2000), it can be hypothesised that the repetition of such perturbations may lead to irreversible modifications of the fish assemblages. Indeed, the levels of ecosystem biodiversity and productivity are not only related to the intensity and duration of disturbance events but also to their frequency (HUSTON 1979).

Some authors claim that no scientifically based method exists for defining the flow regime needed to protect particular fish species (CASTLEBERRY et al. 1996) and others add that the identification of particular enhanced flow regimes for restoring degraded fish communities remains to be done (TRAVNICHEK et al. 1995). This is especially true in the Neotropics where monitoring programmes are difficult to implement for the whole fish community (PONTON et al. 2000). Nevertheless, the present work offers an opportunity to present suggestions that may serve as a basis for a more comprehensive management, sensu PETTS et al. (1989), of the Sinnamary River in which producing electricity and re-establishing natural variations of the flow in the downstream reaches will be weighted equally. Rainfall variations in South America may originate from other causes besides ENSO events (see MOLION 1990 for a discussion), impeding the possibility to develop predictive models of the flow of Guianese rivers for a given rainy season. Nevertheless, it should be mandatory for dam operators to keep the quantity of water released in downstream reaches closer to the base lines, sensu WEILGUNI & HUMPESCH (1999), that can be identified with this study. More specifically, the restoration of periods of high water in May and June, although potentially conflicting with the necessity to produce electricity, appears to be the only way to let fish nurseries play their role in the downstream reaches of the Sinnamary River.

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